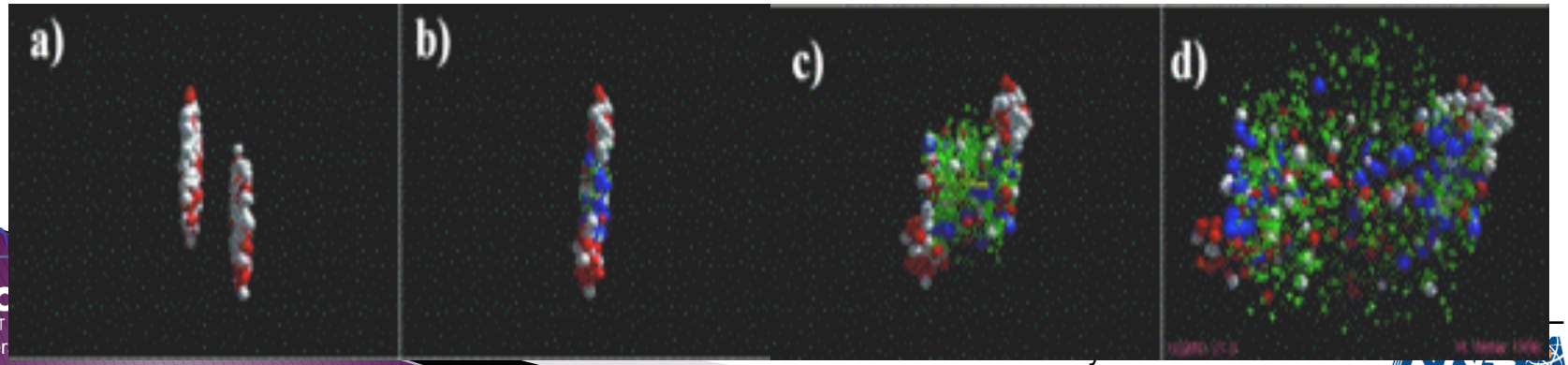
Heavy Ion Program

Nuclear, Particle, Astrophysics and Cosmology (NPAC) Capability Review
14-16 April 2010

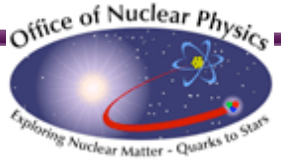
Melynda Brooks, P-25

Overview

- Heavy Ion Physics Program – studying deconfined quarks and gluons through heavy ion collisions.
- Sponsored by DOE Office of Science, Nuclear Physics
- Directly supports the Science Mission and *"Predictions for the state of matter in the early universe, quark confinement…"*
- People involved – P-25 PHENIX Team, P-23 (experimental), T-2 (theory), AOT + ISR (electronics development)
- Peers – PHENIX Groups at BNL (22 scientists + 15 technical staff), ORNL, Livermore



Funds Supporting PHENIX Team Efforts



DOE Supported Efforts

Heavy Ion Physics - RHIC Heavy Ion Physics $2498k/FY10
Medium Energy Physics - RHIC Spin and Cold Nuclear Matter, JLAB $1035k/FY10
FVTX (Forward Silicon Vertex Detector Upgrade Project for PHENIX)
VTX (Barrel Vertex Detector, Upgrade Project) ~$2500k at LANL

LDRD-Supported Efforts

First Unambiguous Measurement of Jet Fragmentation and Energy Loss in the Quark Gluon Plasma
2009-2011 $575k/year
The First Precise Determination of Quark Energy Loss in Nuclei (FNAL E906)
2008-2010 $250k/year
Christine Aidala, Frederick Reines Post-Doc
2009-2011 $180k/year
Andrew Puckett, Director's funded Post-Doc
2009-2010 $125k/year

PHENIX Team, visitors

Technical Staff Members:

Melynda Brooks, Xiaodong Jiang, Jon Kapustinsky, Gerd Kunde, David Lee, Mike Leitch, Ming-Xiong Liu, Pat McGaughey, Walt Sondheim, Hubert vanHecke

Post-Docs:

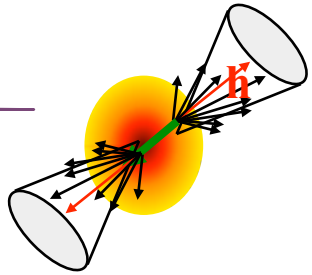
Lei Guo, Han Liu, Zhengyun You, Christine Aidala,, Andrew Puckett, Catherine Silvestre

Students and Full-Time Visitors:

Hisham Albataineh (NMSU, recently graduated), Hussein Al'Taani (NMSU, now at BNL) Hugo Pereira (staff, Saclay), Xiaorong Wang (NMSU staff)

4.9 FTE Staff + 2.5 FTE PD on DOE Heavy Ion funds
1.0 FTE Staff + 3.0 FTE Post-Docs on LDRD funds

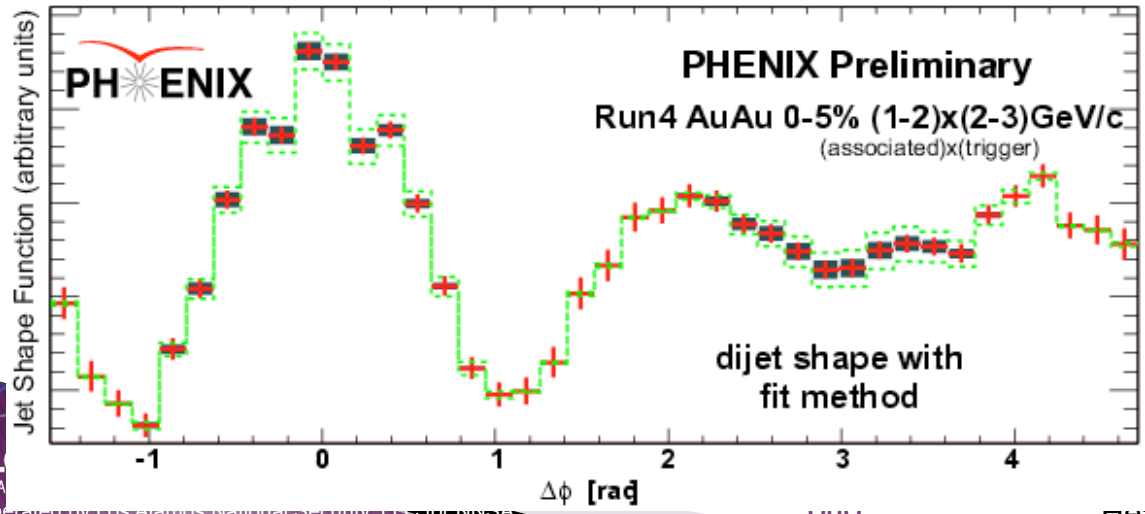
Probing the Quark Gluon Plasma (QGP) – Quark Energy Loss

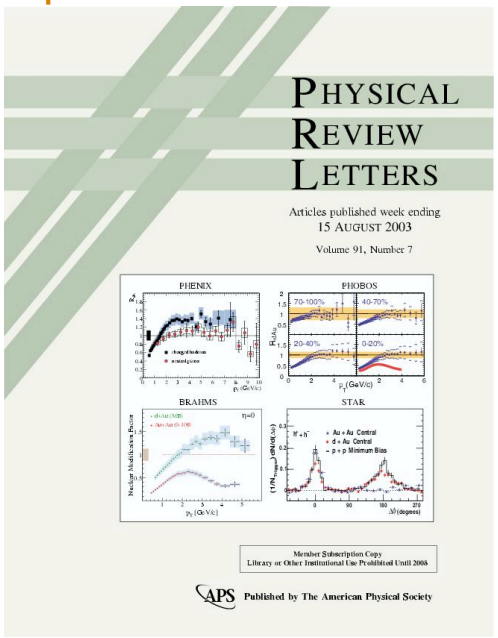


- Quark Energy Loss Measurements in Quark Gluon Plasma (QGP) to Extract QGP Properties:
  - **Leading hadron measurements allow one to infer light quark energy loss (poor-man's jet)**

Leads to prediction of QGP density, but ambiguity from trigger method, jet not fully reconstructed, only constrains light quarks

LANL Contributed (Constantin)





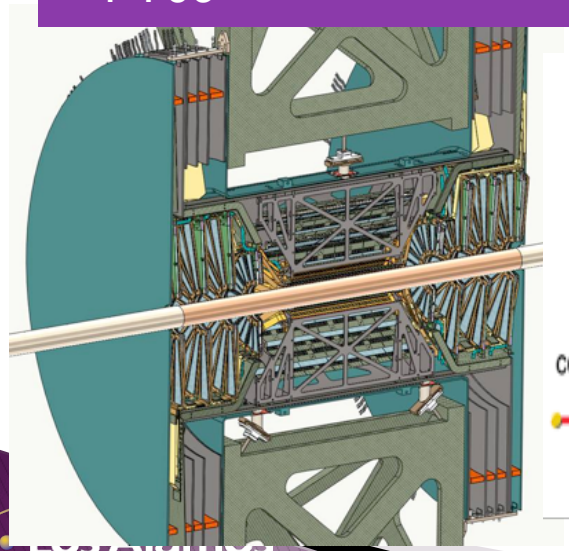
Probing the QGP – Quark Energy Loss

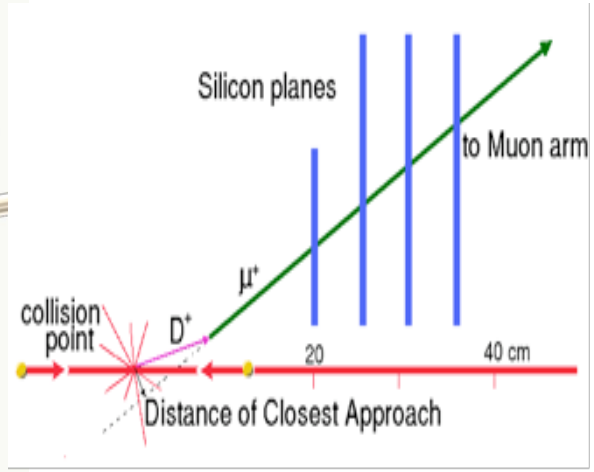
LANL roles:

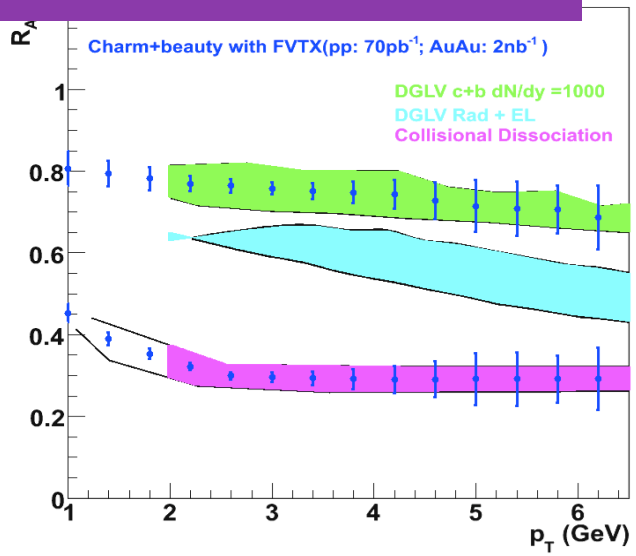
- Project Management of FVTX
- Subsystem management for sensors, readout chips, responsible for DAQ development
- Leading physics program development

*LDRD funded R&D, transitioned to approved $5M construction project in FY09

LA







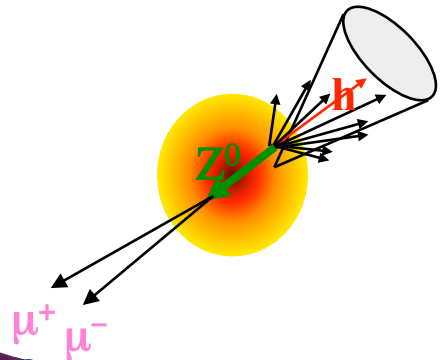
Probing the QGP – Quark Energy Loss

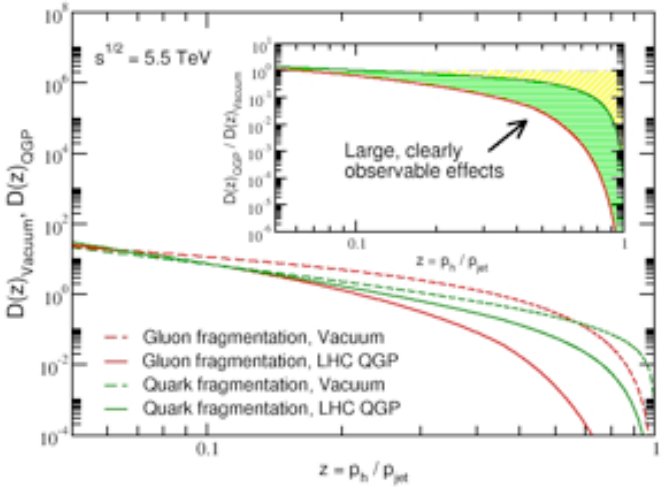
LANL roles:

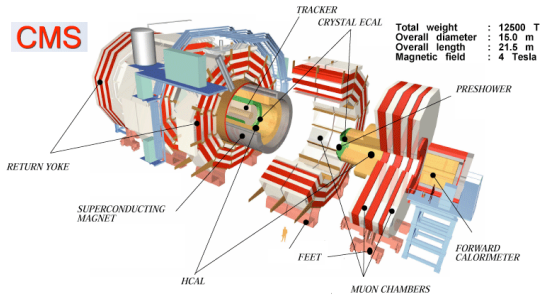
- Produced full simulation of Z^0-tagged jet sensitivity to fragmentation function modifications and will lead real data analysis
- Providing theoretical model development needed to interpret results
- Providing hardware upgrade to CMS Pixel Detector to allow efficient data-taking in Heavy Ion environment

*LDRD funded, expect to transition to DOE funds in FY12

LANL-Led LDRD





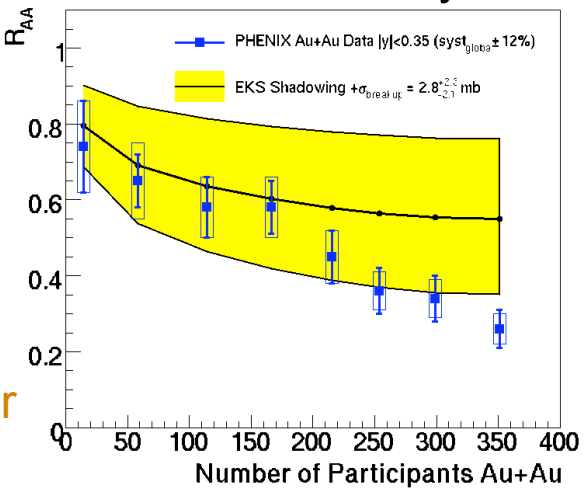


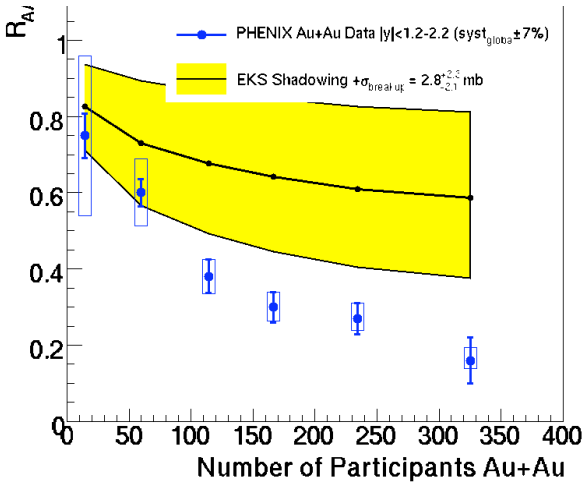
Probing the QGP – Color Screening

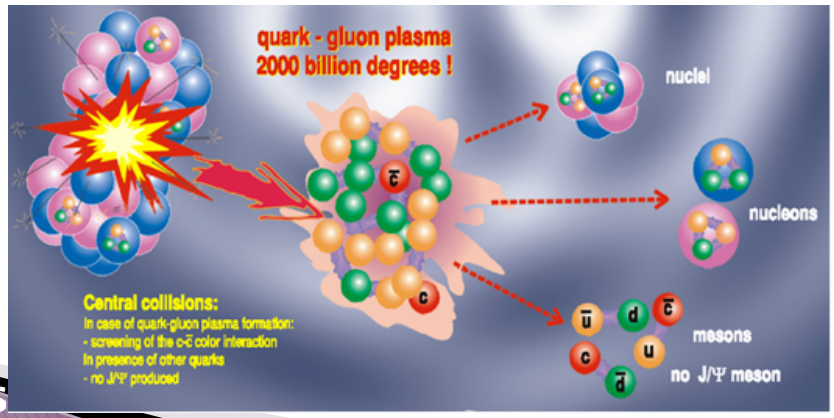
- Color Screening in the QGP
  - Lattice QCD predicts color screening of c-cbar pair (J/ψ precursor) if QGP reaches high enough temperatures
  - RHIC data indicate J/ψ suppression beyond cold-nuclear matter extrapolations

Better cold-nuclear matter extrapolations, other vector meson measurements would better constrain interpretation→More RHIC analyses, FVTX, E906

LANL-led Analysis

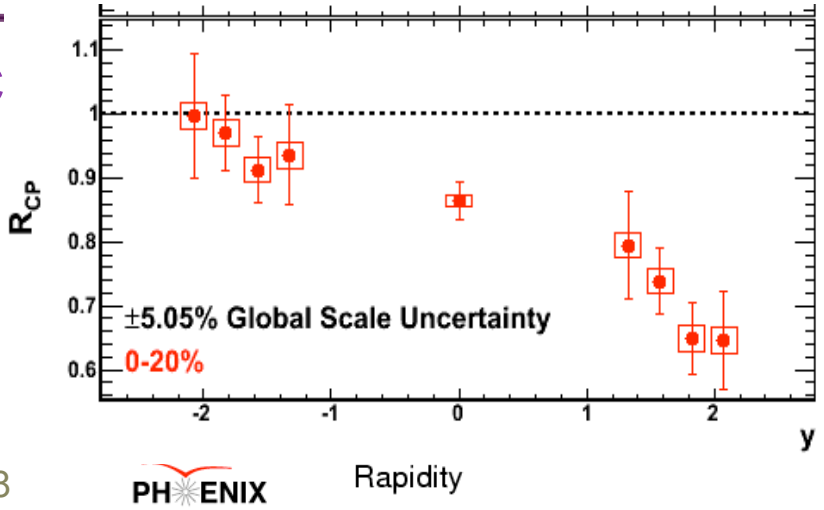


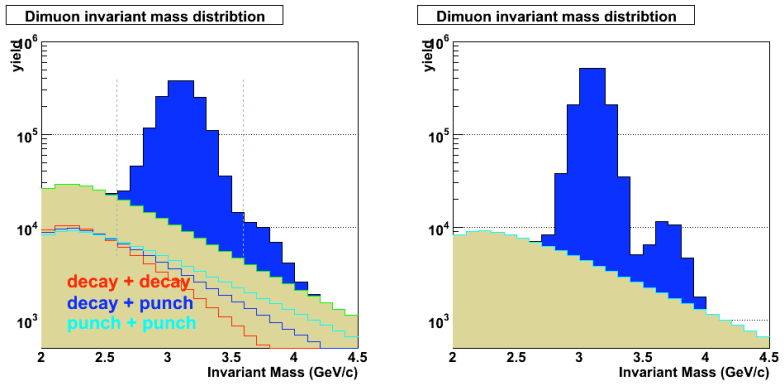


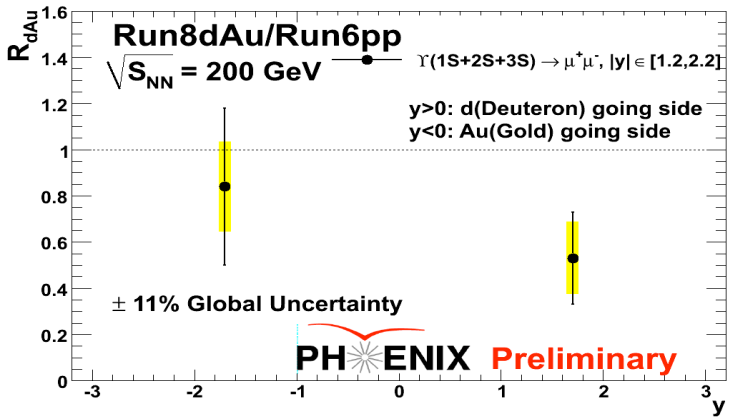


New Vector Meson Measurements in d+Au

- Improved J/ψ measurements from RHIC Run 8
- Upsilon measurements emerging
  - Enabled by increasing luminosities
  - Known to have strong CNM effects from FNAL measurements
  - Leitch, Butsyk, Brooks – p+p ϒ prelim. 2005
  - Kwangbok Lee (Korea U.), Leitch, … working on 2008 +Au & 2006 p+p ϒ data (also working on χ_c using MPC)
- FVTX will allow ψ' measurements





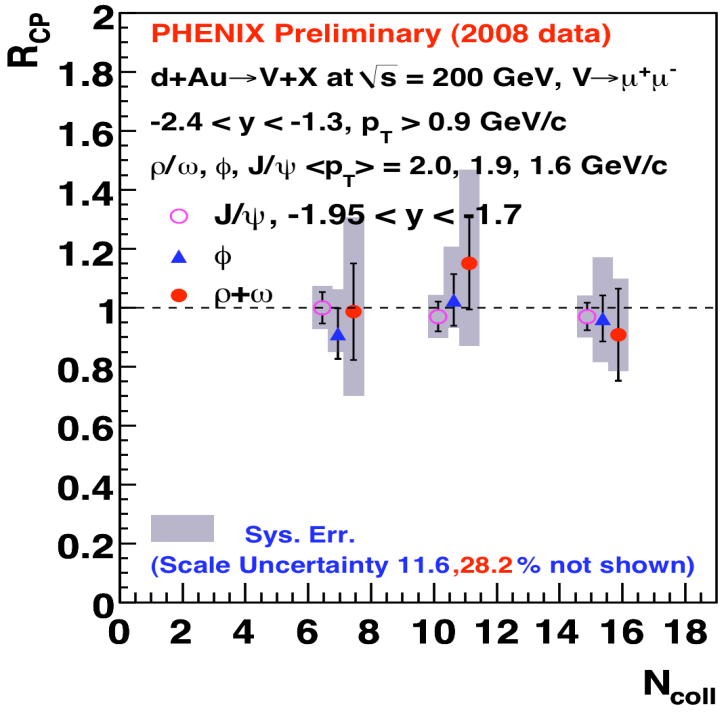


Measurement of ϕ (s-sbar) R_{CP}

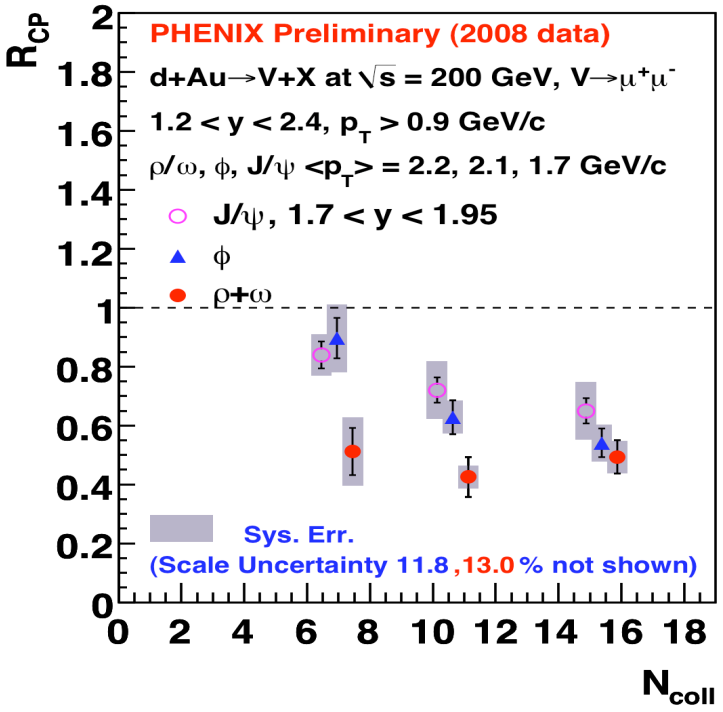
New ϕ analysis from RHIC

- Enabled by increasing luminosities, better trigger
- Lei Guo carrying out full analysis

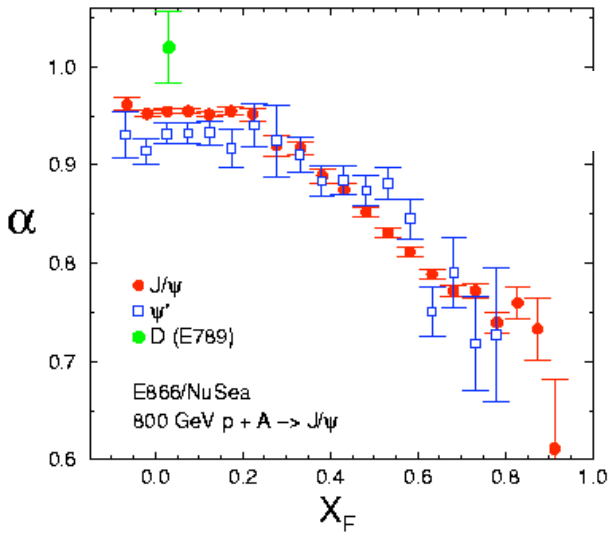
Backward rapidity



forward rapidity



Complexity of Cold Nuclear Matter Effects

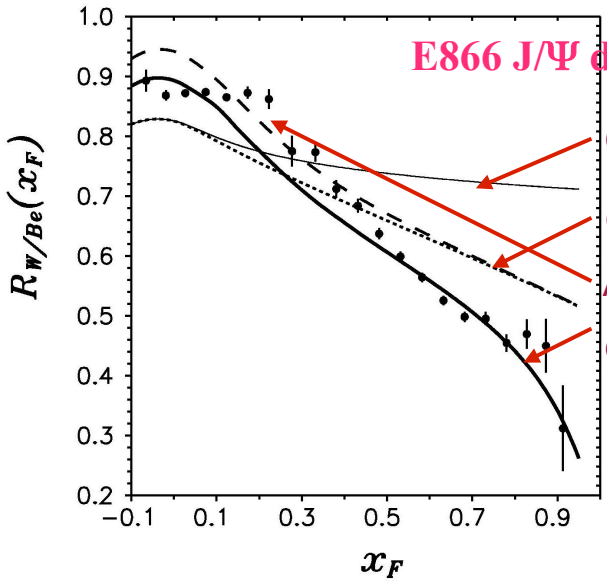


p-Be, Fe, W production of J/Ψ

$\sigma_A = \sigma_N \bullet A^{\alpha}$

A plausible production scenario to explain data:

- Production at low x_F reduced by absorption of J/Ψ and enhanced by anti-shadowing (D not affected and Ψ' absorbed more)
- Some suppression increasing with x_F due to gluon shadowing
- dE/dx shifts x_F and reduces cross section at large x_F

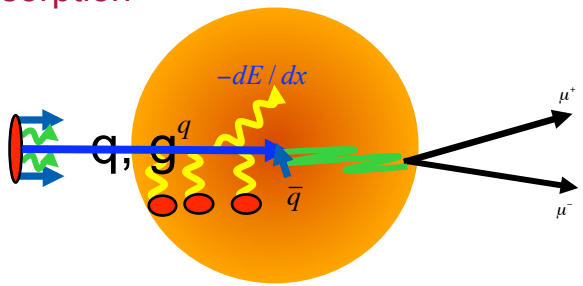


Quark shadowing and final state absorption +

Gluon shadowing +

Anti-shadowing +

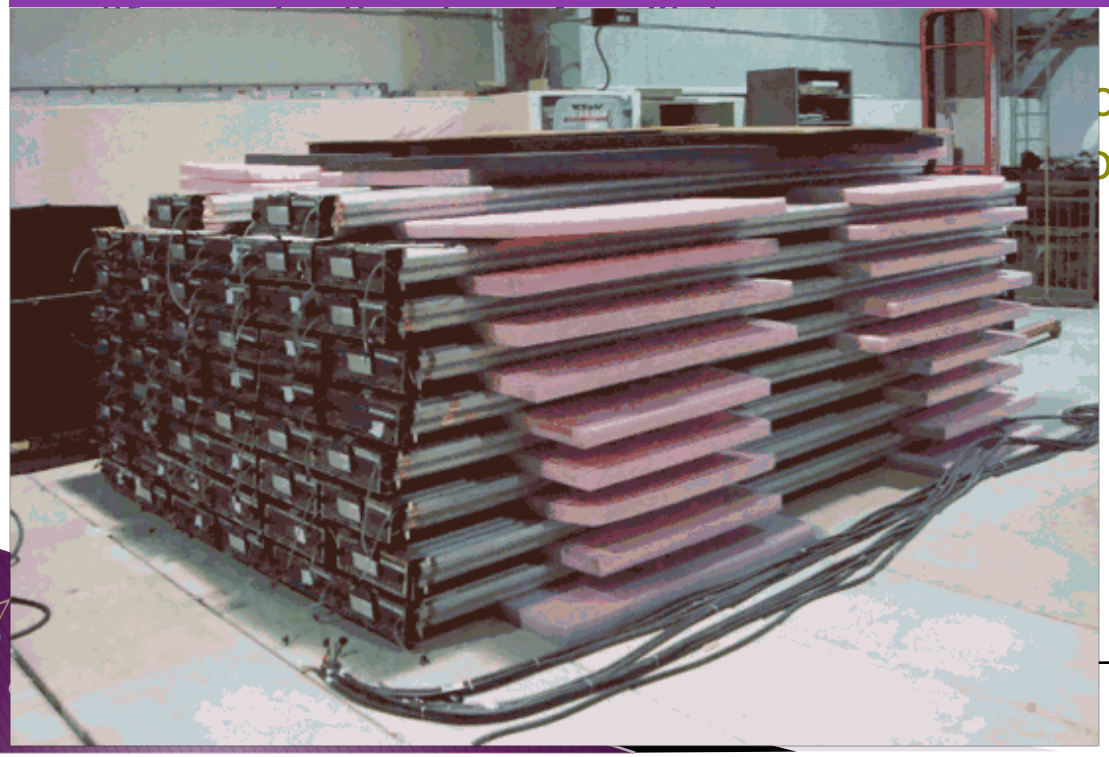
dE/dx

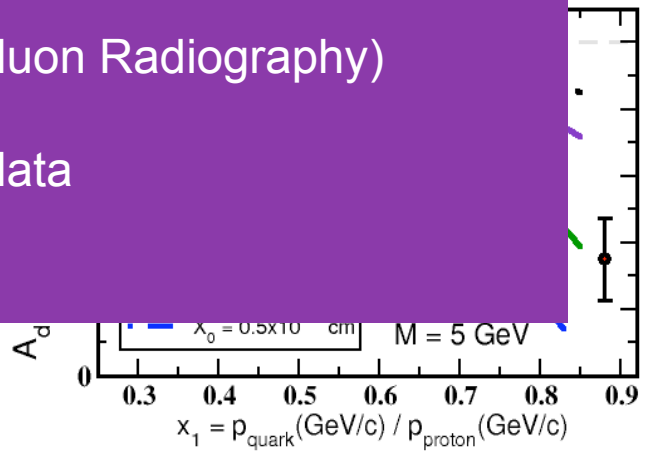


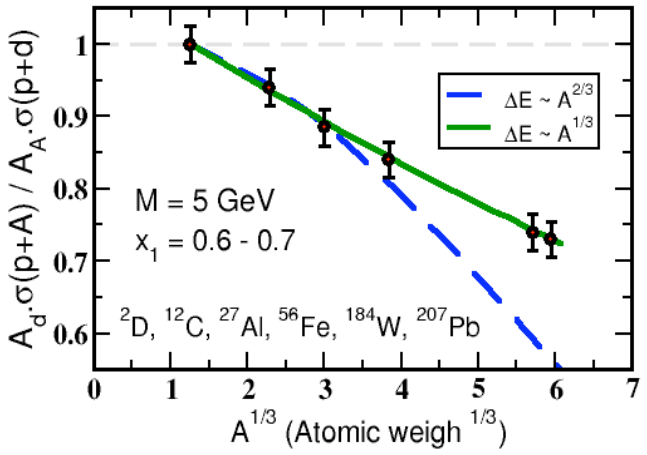
*Kopeliovich, Tarasov, Hufner Nucl Phys A696 (2001) 669-714

FNAL E906 Will Extract Quark Energy Loss

- LANL roles:
  - Providing Muon Identifier (re-purposed from Muon Radiography)
  - Leading energy loss measurement
  - Providing theoretical calculations to interpret data
- *LDRD funded, will transition to DOE funds in FY11

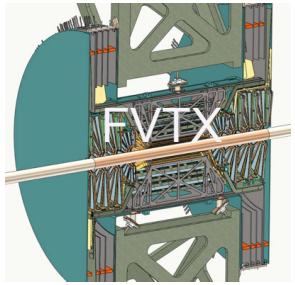


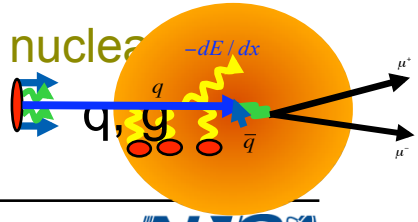




LANL Leadership in Heavy Ions

- LANL Leader in the Heavy Ion PHENIX Collaboration, helping direct the physics program
  - Executive and Detector Council Members, Physics Working Group Conveners, Leading analyses and future directions
- Making Significant Technical Contributions
  - LANL built and supported PHENIX Muon Trackers
  - Leading new Forward Silicon Vertex Detector Project
  - Mechanical oversight for VTX and FVTX
  - PHENIX Upgrades Manager, Run Coordinator, Period Coordinators, on-call technical experts
- Leading New Directions
  - Expanding PHENIX physics program with upgrades
  - Exploring Heavy Ion physics at new energy frontiers (LHC)
  - Working with local theorists, FNAL E906 to disentangle cold nuclear matter effects from quark gluon plasma effects





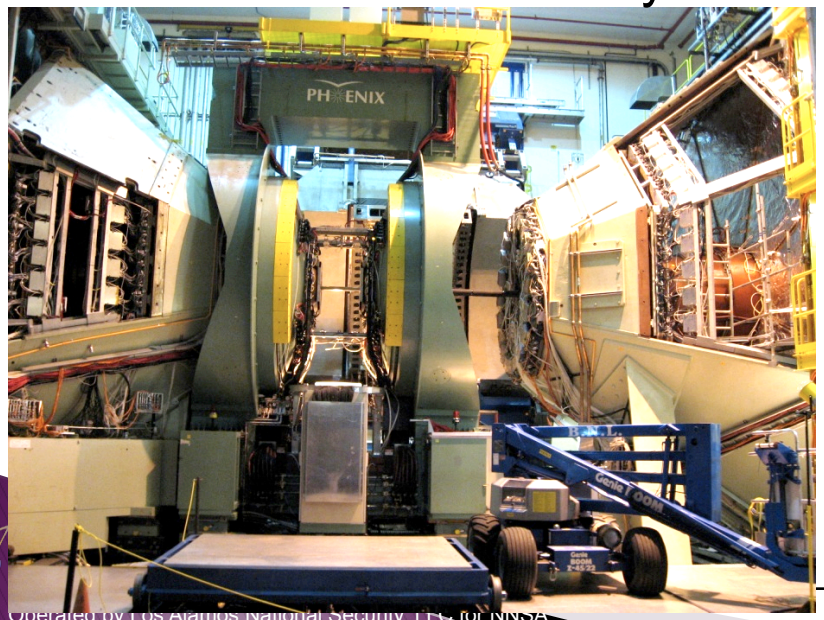
LANL Contributed PHENIX Muon Trackers

Muon Tracker Contributions - Designed, built, installed, commissioned muon tracker systems.

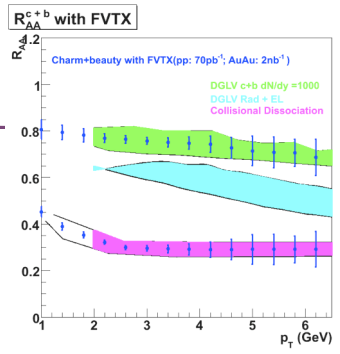
Current Responsibilities - DC Member, provide many on-call expert shifts per run, coordinate and perform maintainence each shut down, working closely with Muon Trigger upgrade

Muon Tracker Analyses - Have provided much of the simulation and reconstruction software, as well as online QA software for the Muon Trackers. Lead roles in most muon physics analyses (sustained staff, post-doc effort required for maintenance of detectors)

Successfully Collecting Data since 2001



Forward Silicon Vertex Detector (FVTX)

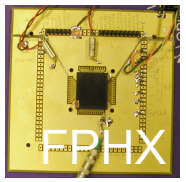


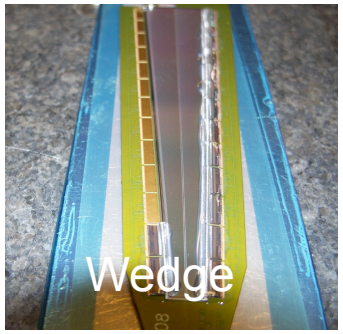
LANL-Led Upgrade Project

- Providing Project Management, DAQ, Sensors Readout Chips, Mechanical Engineering and Integration with VTX

Silicon Sensor Wedge Components

- Prototype sensors procured, tested, and production order placed
- Readout Chip prototypes tested, production order received
- Kapton Interconnect prototype tested, production order placed
- Backplane production order placed





Detector Assembly

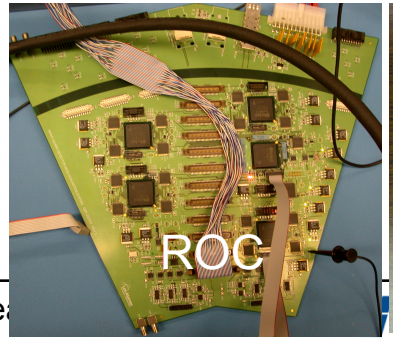
- Wedge fixtures procured, Several prototype wedges assembled
- Full detector assembly areas at BNL prepared

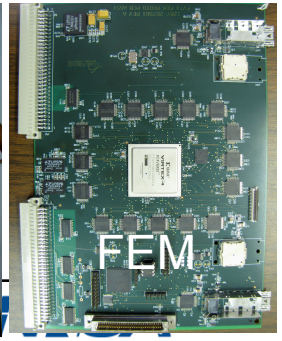
DAQ

- Prototype readout cards procured and tested
- Production this FY

Mechanics

- Mechanical structures designed, procurements underway





Summary

- Leading the understanding of color screening with J/ψ, ψ', upsilon measurements
- Actively working to understand cold nuclear matter effects with measurements from RHIC, E906, work with theorists
- QGP energy loss will be much better understood with the addition of precision open heavy flavor measurements, Z^0-tagged jets
- Providing significant hardware contributions: PHENIX Muon Trackers, FVTX, E906 Muon Identifiers
- Effective use of LDRD funds, transitioning to large DOE-supported efforts

Future Directions

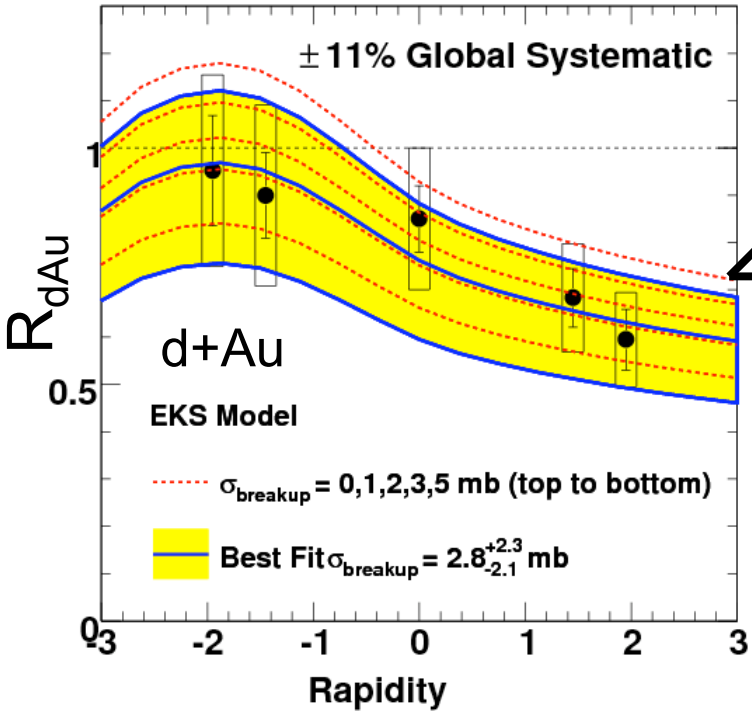
- CNM with RHIC, FVTX, E906

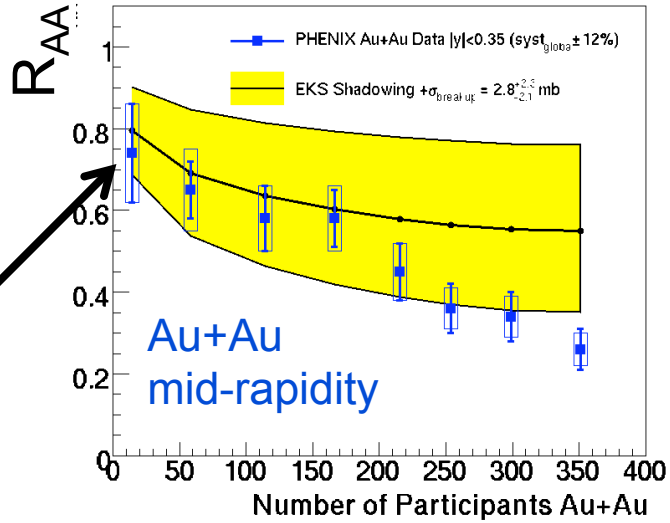
Extrapolating from d+Au to Au+Au

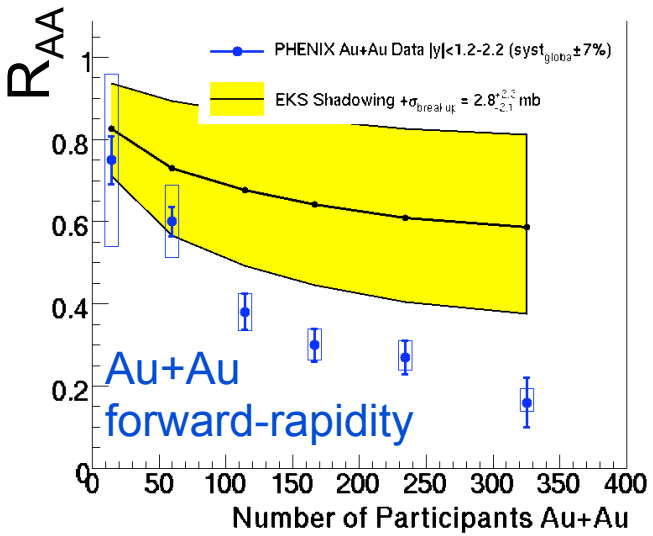
EKS shadowing + dissociation from fits to d+Au J/Ψ data (Leitch, Nagle, Vogt)

- Extrapolated to Au+Au
- But does not include all CNM effects

PRC 77, 024912(2008)
& Erratum: arXiv:0903.4845ne



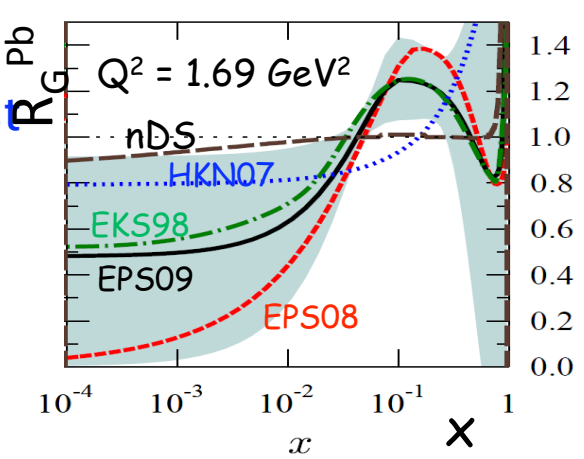


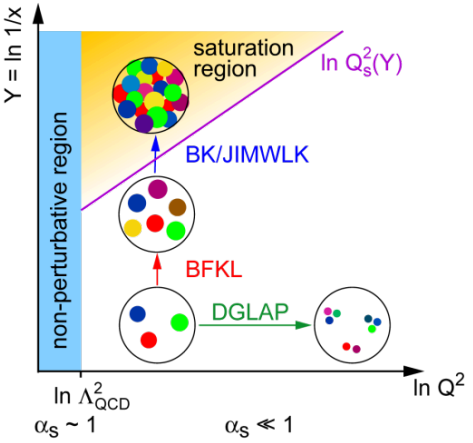


Cold Nuclear Matter (CNM) Physics

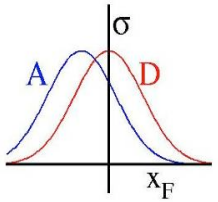
NSAC Milestone: DM8 – "Determine gluon densities at low x in cold nuclei via p + Au or d + Au collisions."

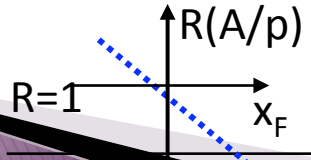
- Leading twist gluon shadowing
- Coherence models & higher-twist (HT) shadowing
- Small-x gluon saturation: 2→ 1 diagrams become important and deplete the low-x region; amplified in a nucleus.

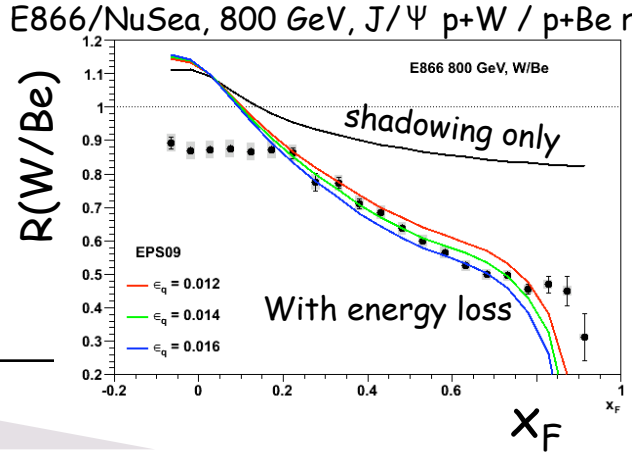




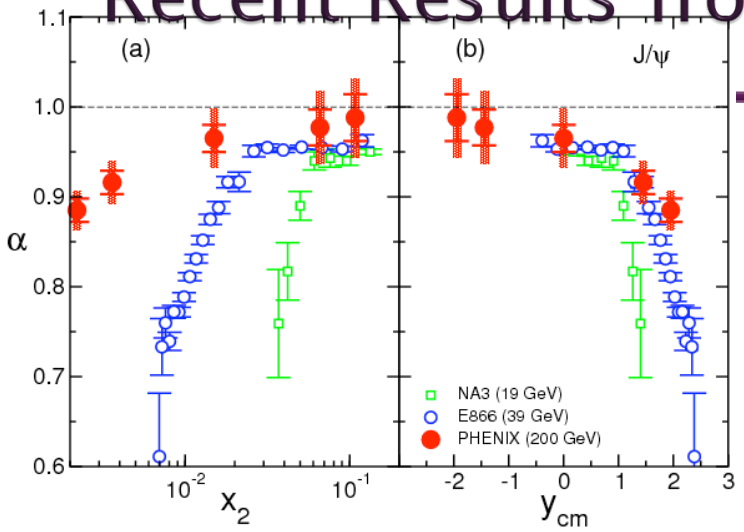
NSAC Milestone: DM12 – "…constrain the mechanism for parton energy loss in the quark-gluon plasma." And what about energy loss in cold nuclear matt…



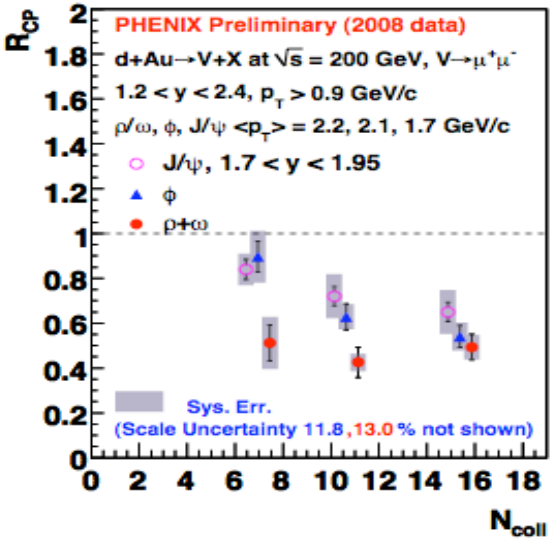




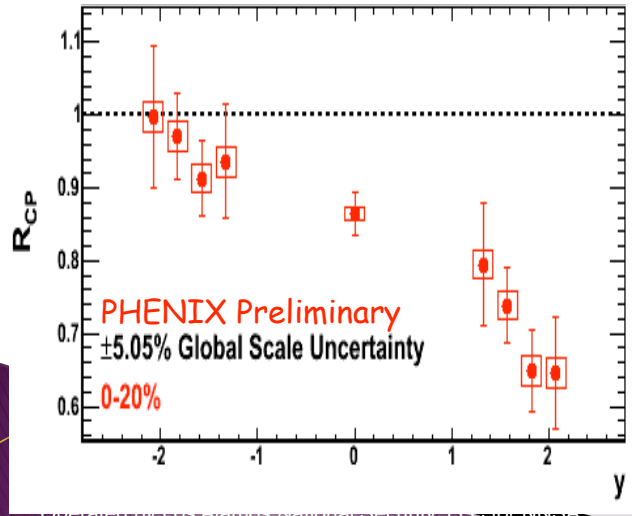
Recent Results from d+Au Collisions



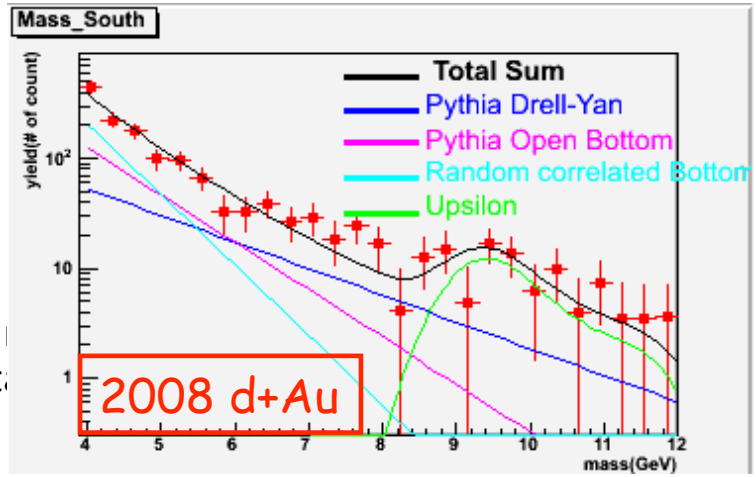
J/ψ suppression in CNM for RHIC d +Au compared to lower energy experiments (Colorado, Leitch, Pereira)



φ, ρ and ω suppression for forward-rapidity (Lei Guo, …)



New J/ψ suppression from 2008 d +Au data (Colorado, Leitch, Pereira)



Upsilon signal i
2008 d+Au dat
(K. Lee (Korea U.), Leitch, …)

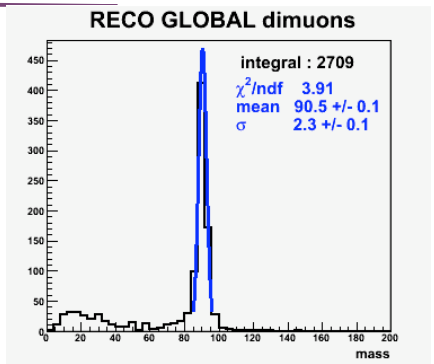
LHC Accomplishments and Results

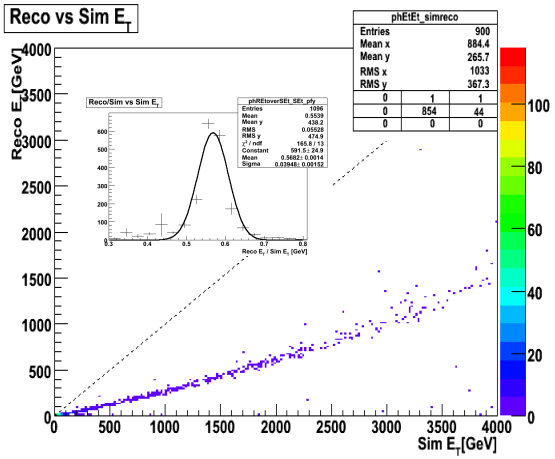
- CMS Dimuon Analysis:
  - Z^0 in heavy ion (year one cross section measurement)
  - Catherine Silvestre now convener of CMS HI dilepton group

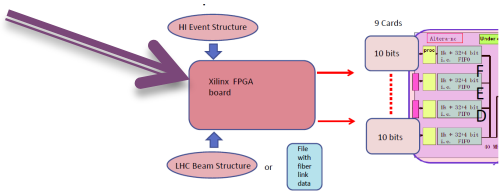
- Developed new important idea for year one Et measurement
  - Analysis package for transverse energy under development

- Heavy Ion Detector Readiness
  - Analyzed Muon Drift Tube performance in heavy ion coll.
  - Detailed MC study of Front End Driver (FED) bottleneck

  - Currently building FPGA based test system to test actual readout sy CERN with realistic HI event and time structure
  - Developing solution for HI pixel readout problem







- Replace the fiber translators with serial receivers for FGPA driven HI events with realistic time structure